The Methods for Improvement of MPEG Picture Quality using the Characteristics of Pixels in Block and Inter-Block Correlations

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ABSTRACT

In this paper, we propose new methods used in MPEG codec that can improve the picture quality degradations of the reconstructed images, such as blocking artifacts, without additional computations. At first, a new 2-step MAD motion search is presented in the motion search and compensation course to reduce the computations and the errors of block boundary pixels. And we also present an overlapped 2-step MAD motion search that use the pixels beyond the block boundary using the reduced computations. In DCT/quantization course for intra-blocks, 1-D DCT predictive quantization and pixel difference predictive quantization, those use the adjacent pixel sets of the previously reconstructed blocks and improve the inter-block continuity, are presented. As simulation results, proposed methods shows better picture qualities by reducing blocking artifacts than that of the conventional MPEG.

블록내 화소특성 및 블록간 상관성을 이용한 MPEG 화질 개선 방법

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요 약

본 논문에서는 계산량의 증가가 없이 MPEG 코덱에 사용되어 블로킹 현상 등 복원영상에서의 화질 열화를 개선하는 새로운 방법들을 제안한다. 먼저 움직임 탐색 및 보상 과정에 2단계 MAD 움직임 탐색 방법을 제안하여 탐색 계산량을 줄이고 블록의 경계 부분의 화소의 왜곡을 줄였다. 또한 줄어든 계산량을 이용하여 블록 경계 너머의 화소를 탐색에 이용하는 중첩 2단계 MAD 움직임 탐색 방법을 제안하였다. 인트라 블록에 대한 DCT/양자화 과정에서는 먼저 복원된 블록의 인접 화소들을 이용하여 적응적으로 양자화 함으로써 블록간 화소의 연속성을 높이는 1차원 DCT 추정 양자화 방법과 화소차 추정 양자화 방법을 제안하였다. 모의 실험 결과 제안한 방법은 일반적인 MPEG에 비해 블로킹 현상을 줄여서 개선된 복원 화질을 보였다.

Key words: MPEG, blocking artifact, motion compensation, MAD, DCT, quantization

1. Introduction

MPEG is an international standard for moving pictures that compress video data efficiently by reducing redundancies existing in an image sequence [1,2].

However the reconstructed pictures using MPEG sometimes have quality degradations because of the native problem of digital video data, i.e., quantized noise, that are seriously increased at the complicated or fast moving scenes. Because motion compensation, DCT (discrete cosine transform), and quantization processes in MPEG codec are performed in the unit of the squared block, the

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probability of the degradation from the discontinuity at the block boundary such as blocking effect and edge broken are always existing. It comes from that there are no processes considering the inter-block correlation in MPEG codec[3,4].

Lots of researches have been progressed to improve the picture quality damaged by inter-block discontinuity. They are classified to several groups. Among them, post-processing methods have been the most popular field up to date. These methods, that reduce the discontinuity between pixels by various tools and filters after frame reconstruction, bring about the improvement at the objective and the subjective pixel qualities. But they have several limitations; 1) the anxiety of blurring is in existence, 2) edges in block boundary are removed, 3) additional process and computation amount are necessary, and 4) result picture quality won't be improved much when reconstructed image has too much damage [5,6].

So, picture quality must be improved through encoding processes above all. Several methods for motion compensation process have been proposed such as overlapped block motion compensation. In these methods, the motion vector is searched by the overlapped block, bigger than the macro-block defined in MPEG, using a well designed 2-dimensional window. They can find the block that has good continuity with neighboring block as a compensated block, therefore blocking artifacts can be reduced. But windowing at all the searching points with the bigger block size than macro-block inevitably increase the computation amount extremely at the motion compensation process that already occupy the major portion in the overall MPEG codec. From this reason, it can be hardly practical to apply to MPEG codec [7,8].

Another group is using LOT (lapped orthogonal transform) methods. In them, transform is performed by the unit of the overlapped block, bigger than the sub-block, the divided macro-block for the transform course, to reduce the block boundary error. It also goes with additional computations, and high frequency cancellations can be occurred when the transmitted coefficients are adjusted to that of MPEG defined sub-block[9].

In this paper, we propose several effective techniques that can reduce blocking artifacts by considering inter-block correlation in MPEG codec. 2-step MAD (mean absolute difference) motion search is presented for motion compensation process. When the MAD is used in motion search, the error between the original block and the compensated block is outstanding at the boundary pixels compared with inner-block pixels. This phenomenon is from that the distortion are decided by inner-block pixels highly correlated each other, and it can be one of the cause of blocking artifacts. So we divide the mass of MAD by two parts, boundary-pixel MAD (BMAD) and inner-pixel MAD (IMAD), and calculate BMADs of candidate blocks firstly in the search range. Then IMADs are calculated only for the new candidate blocks that have the BMADs less than the predefined threshold, and whole MADs for finding the compensated block are obtained with the reduced candidate blocks. This method can prevent the probability that candidate blocks, that have excessive boundary pixel errors, could be a compensated block. The number of points for calculating difference between pixels are reduced because of the rejected blocks at first step. So we can present the overlapped 2-step MAD search that include pixels beyond the block border for BMAD substituted for these spare points. This overlapped version can improve inter-block continuity at the compensated block without raising the computation amount.

In the DCT and quantization process for intra-block, we present the predictive methods using adjacent pixels in the previously reconstructed blocks. They are based on the characteristics that the mean pixel value and the edge direction are continuous between neighboring blocks. 1-D (dimensional) DCT predictive quantization method com-

putes 1-D DCT coefficients for adjacent pixel sets in the previously reconstructed above and left blocks from the current block in the current frame. Then the average of their DC (the lowest coeficient)s compensates the DC of current block instead of conventional DC DPCM (difference pulse code modulation). We predict the grade of vertical and horizontal edges laid in the current block by the magnitude sums of the remaining each AC coefficient sets, and apply them to the weighting of the corresponding 2-D DCT quantization matrix coefficients for an adaptive quantization. And another proposed pixel difference method predicts the DC coefficient of the current block using the average of adjacent pixels of the previously reconstructed blocks, and obtains the weightings by the sum of the horizontal and vertical differences of above and left block pixels that are able to have the vertical and horizontal edges extended to the current block. This is technique can reduce the additional computation load.

2. Motion Compensation

MPEG coder remove temporal redundancy by BMA (Block Matching Algorithm) in the unit of macro-block, commonly 16×16. In BMA, the compensated block is decided as the minimum distortion block from current block, moving matching point pixel by pixel in the predefined search region in the reference frame. MPEG coder gets the error block between this compensated block and original block, and classify current block into inter or intra-block by their variances. The motion vector, the location of compensation block in the reference frame, is transmitted and the MCDI (Motion Compensated Difference Image) block is transformed in the case of inter. While a original block is transformed if the class is intra.

Both MSE (Mean Squared Error) and MAD are used as distortion measures between current block and candidate blocks in MPEG. Because MSE needs much square-operations for every pixels in each searching point, almost all MPEG coder adopt MAD for its low computation amount. The correlation between the neighboring compensated blocks is very low because these block based distortion measures can find only the mathematically minimum error block without considering about real motion.

Fig. 1 shows the mean squared pixel differences after motion compensation by an experiment, and shows that the errors of boundary pixels are more serious than those of inner pixels. As adjacent pixels used to have similar luminances, the inner pixels that have more adjacent pixels than boundary pixels in a block contribute massively to total error, and boundary pixel errors between the current block and the compensated block become prominent. This means that inter-block continuity can be cut off, and blocking artifacts can be caused.

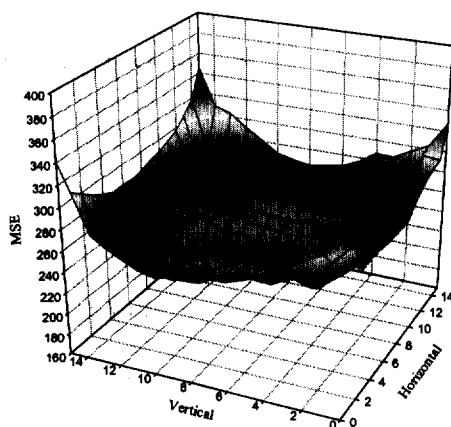



Fig. 1. The mean squared pixel differences for inter-blocks after motion compensation by conventional MPEG.

2-1. 2-Step MAD Motion Search (TSMS)

In this paper, new 2-step MAD motion search method is proposed to lessen the drawback of general MAD search using that boundary pixel errors are greater than those of inner pixels.

This method computes boundary-pixel MAD (BMAD)s, illustrated in Fig. 2, between current block and candidate blocks in searching range at

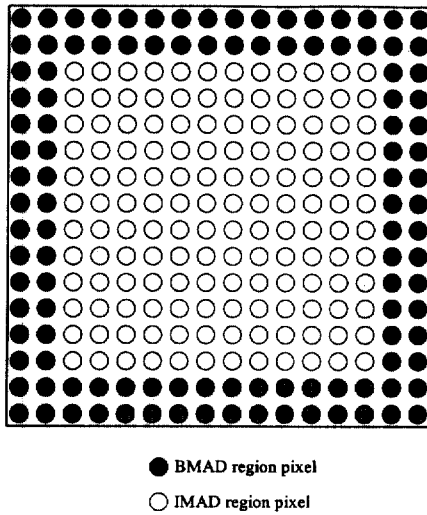



Fig. 2. BMAD and IMAD regions in a block for 2-step MAD motion search.

Fig. 3. The mean squared pixel differences for inter-blocks after motion compensation by 2-step MAD motion search.

the first step. And only inner-pixel MAD (IMAD)s of which BMADs are less than the predefined threshold are found at the second step. Finally whole MADs of blocks to find the compensated block are decided by the sums of BMAD and IMAD. As the pixels for BMAD and IMAD are 112 and 144 respectively, BMAD can contribute to this sum slightly more than IMAD without additional computation and the blocks that prevent blocking artifacts can be searched.

In this method, the inter-intra classification by computing variances of current original block and MCDI block are never used because it is capable by the BMAD threshold. If all the BMADs of candidate blocks get over the threshold at the first step, current block is classified as a intra-block. Threshold are defined as the value that the ratio of inter-block to intra-block can be maintained as that of conventional MPEG coder, for the same amount of generated bits. It can reduce blocking artifact of inter-block by preventing the candidate block that have a big boundary pixel difference and small whole MAD to be a compensated block. Fig. 3 shows the mean squared pixel differences of MCDI block after motion compensation by this method, and proposed method can reduce the errors of boundary pixels comparing Fig. 1. From these results, Blocking artifact can be improved and generated bits can be reduced additionally for its low mean and variation. The number of points for calculating pixel difference are reduced because IMADs of rejected blocks at the first step are unnecessary to be computed.

2-2. Overlapped 2-step MAD motion search (OTSMS)

We also propose an high-performance overlapped motion search using overlapped BMAD (OBMAD). Reduced points that calculate pixel difference by using 2-step MAD search can extend the range of boundary pixel beyond the border of the macro-block to the pixels of neighboring block as shown in Fig. 4.

That is, an overlapped motion searching method can be possible within the computation amount of conventional MPEG; according to the result of our simulation. Fig. 5 shows the mean squared pixel differences after motion compensation by this method, that improve the performance even more than the plain 2-step method as expected.

3. DCT/Quantization

Blocking effect also can be provoked by intra-

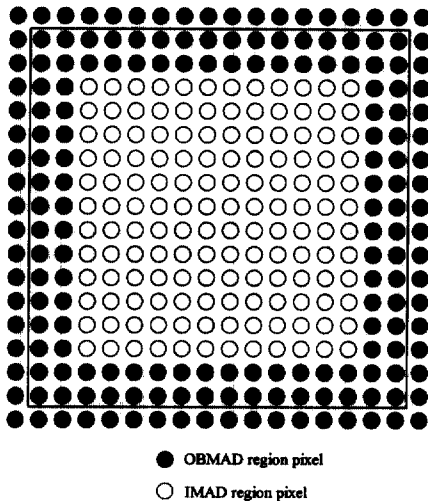



Fig. 4. OBMAD and IMAD regions in a block for the overlapped 2-step MAD search.

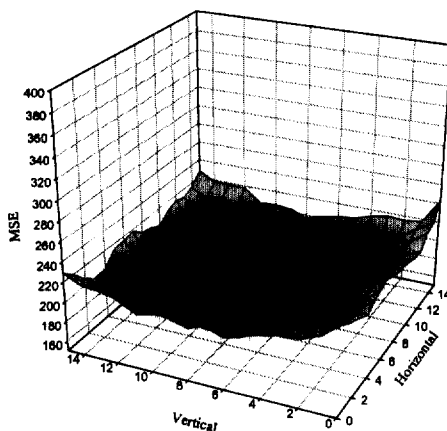



Fig. 5. The mean squared pixel difference by the overlapped 2-step MAD search.

blocks from the reason that the quantization noise at intra-blocks is distinguished, because the coder leaves out the motion compensation and has to encode the original block, of that dynamic ranges of pixel values are very high. In particular, DC coefficients of those are extremely bigger than other coefficients, so it can be the one of cause of blocking artifact.

A MCDI block and a macro-block are splitted to sub-blocks and go to the transform and quantizaton course. 8×8 2-D DCT is commonly used in MPEG coder. DC coefficient of that goes to the DPCM course, in that DC coefficient is subtracted by the predictive obtained by left block DC, if left block is also intra, or assumed grey level, 128, else. Then sub-blocks are quantized with a quantization matrix. the default quantization matrix was predefined by considering HVS (human visual system) and the bit amount experimentally generated. In spite of using this, the quantized coefficient power of intra block is still greater than that of inter block. Intra-blocks are usually distributed sparsely in P (predictive) or B (bidirectional predictive) frame, so the quality degradations at them are used to be looked prominent to human eyes subjectively. So it is more important to reduce inter-block discontinuity in the block classified to intra.

3.1 1-D DCT Predictive Quantization (ODPQ)

There exist edge continuities between neighboring blocks in common video images. But it is difficult to consider them under the DCT coefficient peculiarity that can eliminate only inter-pixel redundancies sub-optimally. Moreover it is possible that intra and inter-block is mixed in a frame and the DCT coefficients of the inter-block do not imply the mean value and the edge information of the original block.

In proposed methods, we pick up two sets of adjacent pixels out of reconstructed above and left block illustrated in Fig. 6, and perform 1-D DCT with the pixel sets to use as the predictive of current block.

At first, the prediction value for DC is calculated by averaging above and left DCs, and this DC DPCM is also used in conventional MPEG. Generally not only mean pixel value between neighboring blocks, but also edges are continuous to current block along the related direction. AC coefficients bearing edges of current block are also related to the ACs of adjacent 1-D DCT sets. But it is very hard to predict them because the successive edge is expressed as all frequency components and different signs. So AC sets are used

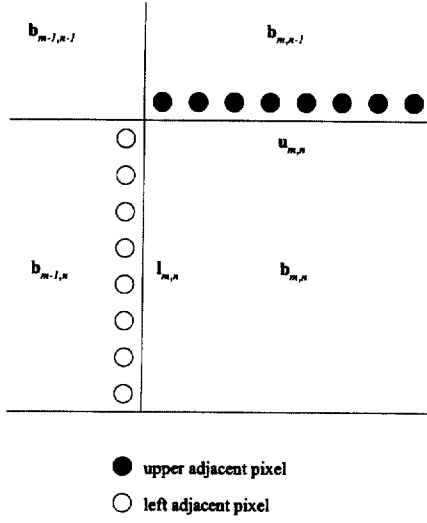



Fig. 6. Above and left pixel sets of neighboring reconstructed blocks.

in quantization course. Although the intra quantization matrix was designed properly, the patterns of intra-blocks are greatly various and it is somewhat unreasonable to cover them with single matrix.

Hence in this paper, we emphasize the coefficients of successive edge by controlling the elements of the quantization matrix by adaptive weightings using above and left 1-D DCT sets. A vertical edge is able to be successive to current block if the magnitude of above set is high, and left is to be horizontal respectively. In advance vertical and horizontal activities are calculated from the sums of absolute of above and left AC magnitudes as belows:

$$A^{v}_{m,n} = \sum_{x=1}^{S-1} |U_{m,n}(u)| \qquad (1)$$
$$A^{h}_{m,n} = \sum_{y=1}^{S-1} |L_{m,n}(v)|$$

when $U_{m,n}(u)$ and $L_{m,n}(v)$ are upper and left block's adjacent 1-D DCT coefficient sets.

Let α, β is 50% and 90% points of its CDF shown in Fig. 7. Vertical and horizontal weightings are converted from these points by a function illustrated in Fig. 8. And these obtained weightings

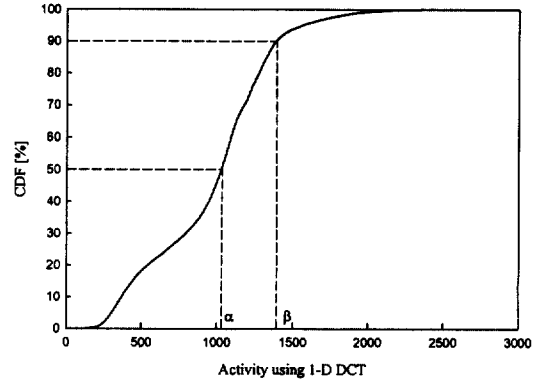



Fig. 7. The activities and α, β points using 1-D DCT predictive method.

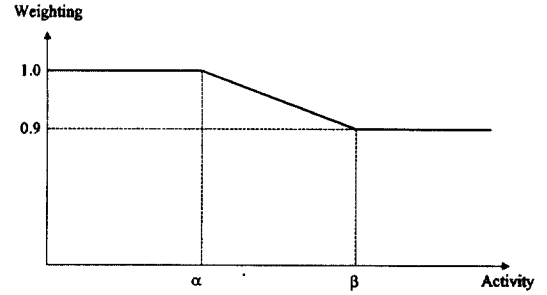



Fig. 8. The function to compute weightings using activities.

are multiplied to the corresponding elements of current block's 2-D DCT, that imply vertical and horizontal edge, illustrated in Fig. 9 [10]. This predictive method can prevent quantization noise came from coarse quantization on expected edge, and never have any local loss comparing with MPEG because the weighting value is 1, equal to default matrix, if prediction is in failure. So the proposed 1-D DCT predictive method can reduce DC coefficient by a large margin and increase coding efficiency. And the continuous edge can be recovered by enlarging corresponding coefficients by reasonable prediction.

3.2 Pixel Difference Predictive Quantization (PDPQ)

The ODPQ mathod, explained above, may cause the increment of the computation amount for

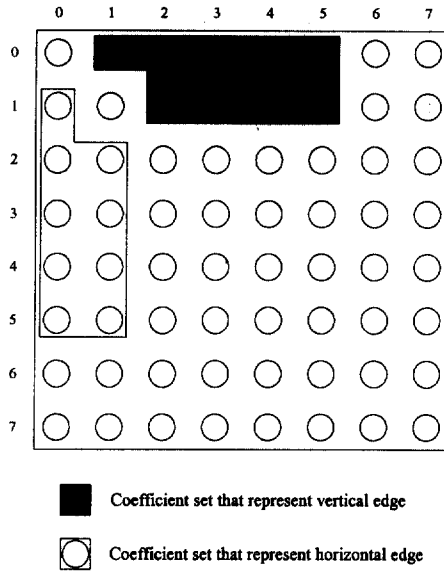



Fig. 9. DCT coefficient sets representing vertical and horizontal edges.

Fig. 10. Adjacent pixel sets used in pixel difference predictive quantization.

calculating DCT for above and left pixel sets. But it is worthy because it is just applied to intra-blocks, of that occupy about 10% out of entire blocks in general.

So in this paper, an pixel difference method is also presented to reduce these multiple operations. This method calculates the differences of pixels, in horizontal direction for above and vertical direction for left respectively, that can detect edges capable to be continuous to current block instead of 1-DCT. Fig. 10 shows the adjacent above and left pixel sets and the directions of calculating pixel differences for current block used this method. And new Vertical and horizontal activities are computed by sums of differences of each set as belows:

$$A^{v}_{m,n} = \sum_{u_{m,n}(x,y),\, u_{m,n}(x+1,y) \in \mathbf{u}_{m,n}} |u_{m,n}(x,y) - u_{m,n}(x+1,y)|$$

$$A^{h}_{m,n} = \sum_{l_{m,n}(x,y),\, l_{m,n}(x,y+1) \in \mathbf{l}_{m,n}} |l_{m,n}(x,y) - l_{m,n}(x,y+1)| \qquad (2)$$

And weightings are obtained as the same way of 1-D DCT methods.

4. Simulations and Discussions

Our simulations consist of two parts. At first, they were performed just about motion compensation and DCT/quantization courses performed to analysis each proposed method and to obtain useful parameters using general images. And secondly, the compositions of proposed methods are applied to software MPEG codec based on TM (test model) 5 made by MPEG software group in June 1994, and performance improvements are discussed.

The outputs of first simulation are used in the illustrations of the above section 2 and 3, and particularly obtained thresholds are used for software MPEG codec explained next. Here, motion prediction mode is only forward prediction and recovered, that is widely used to test motion search and encoding methods easily. As test images, 50 frames of 352×240 sized FOOTBALL, FLOWER GARDEN each, 50 frames of 352×288 sized SALESMAN, and 30 frames of 720×480 sized MOBILE. And all the sequences are progressive scanned.

The thresholds for classifying inter and intra-block, used in 2-step MAD motion search and the

overlapped search are decided by the generated bit matching to conventional MPEG. Fig. 11 shows the ratio of inter-block by varying BMAD threshold and 20 become a reasonable threshold. and 25 is chosen for OBMAD by the same way. The results from our methods to inter-block are presented in Fig. 1, 3, and 5 above. And the statistics for intra-block are also used for finding α, β stated above. From them, we confirm that our predictive methods can reduce the power of coefficients after quantization, that expresses the amount of transmitted informations, for both inter and intra classed block, and expected good performance when applying to full MPEG codec. Table 1 shows the reducing of the operations, that expresses the time of encoding pictures, of proposed methods compared with conventional MPEG.

To test the performances of the proposed techniques in practical, we applied them to software MPEG full codec. Test images are each 90 frames of progressive 352×240 size four SIF sequences:

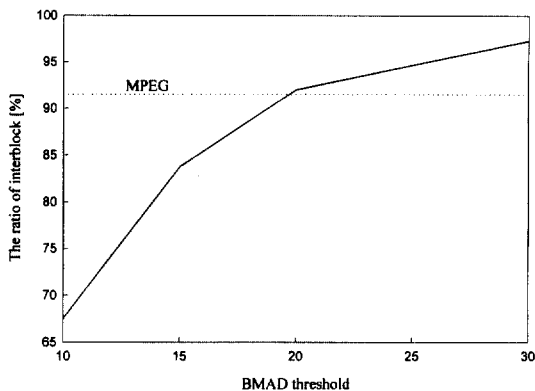



Fig. 11. The ratio of interblock by varying BMAD threshold.

FOOTBALL has somewhat large and irregular motions, FLOWER GARDEN has regular motions by camera panning and complicated edges, MOBILE and TABLE TENNIES have partial motions and scene changes. The most commonly used image quality criterion, PSNR, is used to compare objective quality.

Table 2 compares performances PSNR and the bit rates of the combinations of proposed methods. PSNR results of proposed methods are all outstanding compared with the results of MPEG. They tell us that our predictive values go with real values well and inter-block continuities are improved properly. But in the other side, amount of generated bits are not much reduced. It is by the reason that the reduced data from 2-step MAD search and predictive quantization have alleviated buffer states and used for fine quantization by rate controller. That is, bit amount can be reduced by our methods, and it is consumed to enhance picture quality more by the feed back characteristics of MPEG.

Fig. 12 shows the PSNR results for the reconstructed FOOTBALL 90 frame by proposed TSMS-PDPQ combination, the most simple scheme, and conventional MPEG. We can obtain higher PSNR results at every frames by using proposed methods. The comparisons of the reconstructed images are shown in Fig. 13 and 14. We can see that a blocking artifact in the part of players knee in Fig. 13 are reduced and a successive edge such as the number 11 in calendar in Fig. 14 can be preserved by proposed methods. Consequently, we confirm that our methods can improve inter-block continuity in MPEG codec.

Table 1. The computation increments of proposed methods comparing with MPEG coder

Proposed method	The increment of operations per block		The increasing ratio of operations per block [%]	
	Addition	Multiplication	Addition	Multiplication
TSMS	-73368	+1	-33.47	0
OTSMS	-16780	+1	-7.66	0
ODPQ	+11.52	+88.20	+0.18	+0.17
PDPQ	+5.76	+1.80	+0.09	0

Table 2. The comparison of average performances for reconstructed images using conventional MPEG and the combinations of proposed methods

		FOOTBALL	FLOWER GARDEN	MOBILE	TABLE TENNIS
MPEG	PSNR [dB]	28.73	26.96	24.72	33.29
	Bit rate [bpp]	0.62	0.62	0.63	0.62
TSMS-ODPQ	PSNR [dB]	29.29	27.10	25.36	33.66
	Bit rate [bpp]	0.62	0.62	0.63	0.62
TSMS-PDPQ	PSNR [dB]	29.28	27.10	25.35	33.66
	Bit rate [bpp]	0.62	0.62	0.63	0.62
OTSMS-ODPQ	PSNR [dB]	29.39	27.48	25.58	33.66
	Bit rate [bpp]	0.62	0.62	0.63	0.62
OTSMS-PDPQ	PSNR [dB]	29.39	27.48	25.57	33.66
	Bit rate [bpp]	0.62	0.62	0.63	0.62

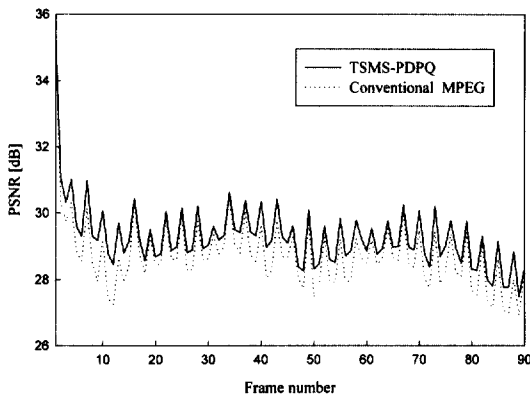



Fig. 12. The PSNR results for the reconstructed FOOTBALL sequence by proposed TSMS-PDPQ combination and conventional MPEG.

(a) (b)

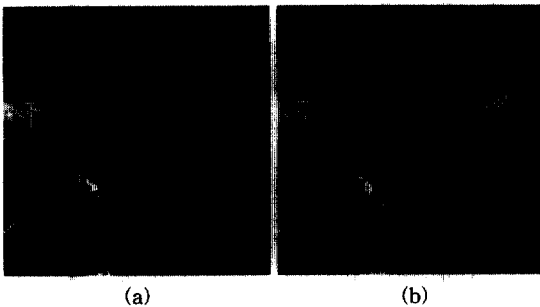



Fig. 13. Partially enlarged images of FOOTBALL 14th B-frame reconstructed by (a) conventional MPEG and (b) TSMS-ODPQ.

5. Conclusions

In this paper, we propose effective methods that can reduce picture quality degradations such as

(a) (b)

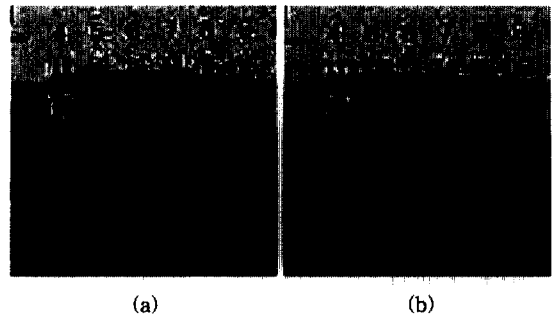



Fig. 14. Partially enlarged images of MOBILE 13th B-frame reconstructed by (a) conventional MPEG and (b) OTSMS-PDPQ.

blocking artifact came from inter-block discontinuity for MPEG codec.

At motion compensation process, two methods are presented which do not create extra computation. 2-step MAD motion search and overlapped 2-step MAD motion search reduce compensating errors of boundary pixels and include the pixels beyond block boundary. As results, the error distribution becomes flat and lower for interblock. And two methods in DCT/quantization process for intrablock coding are also presented. The prediction for DC coefficient and the predictive quantization by giving reasonable weightings to quantization matrix by 1-D DCT and pixel difference methods can improve inter-block continuity.

From experiments, we confirm that our method can reduce blocking artifact and shows better performance than plain MPEG.

References

[1] K. R. Rao and J. J. Hwang: *Techniques and Standards for Image, Video, and Audio Coding*, Prentice Hall, 1996.

[2] J. L. Mitchell, W. B. Pennebaker, C. E. Fogg, and D. J. LeGall: *MPEG Video Compression Standard*, Champman and Hall, 1997.

[3] B. Jeon and J. Jeong, "Blocking Artifact Reduction in Image Compression with Block Boundary Discontinuity Criterion," *IEEE Trans. on Cir. and Sys. for Video Tech.*, pp. 345-357, vol. 8, no. 3, Jun. 1998.

[4] S. A. Karunasekera and N. G. Kingsbury, "A Distortion Measure for Blocking Artifacts in Images Based on Human Visual Sensitivity," *IEEE Trans. on Image Processing*, pp. 713-724, vol. 4, no. 6, Jun. 1995.

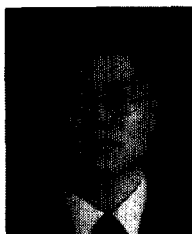
[5] B. Ramamurthi and A. Gersho, "Nonlinear space-variant postprocessing of block coded images," *IEEE Trans. on Acoustics, Speech, Signal Processing*, vol. ASSP-34, no.5, pp. 1258-1268, Oct. 1986.

[6] H. C. Kim and H. W. Park, "Signal adaptive postprocessing for blocking effects reduction in JPEG image," *Proceeding of ICIP*, vol. 2, pp. 41-44, Sep. 1996.

[7] H. Watanabe and S. Singhal, "Windowed motion compensatation," *Proc. SPIE Conf. Visual Commun. and Image Process.*, pp. 582-529, vol. 1605, 1991.

[8] M. T. Orchard and G. J. Sullivan, "Overlapped block motion compensation: An estimation-theoretic approach," *IEEE Trans. Image Process.*, pp. 693-699, vol. 3, no. 5, Sep. 1994.

[9] H. S. Malvar, "Biorthogonal and Nonuniform Lapped Transforms for Transform Coding with Reduced Blocking and Ringing Artifacts," *IEEE Trans. Signal Process.*, pp.1043-1053, vol. 46, no. 4, Apr. 1998.

[10] H. Cho, B. Choi, K. Lim, S. Kim, and J. Ra, "A Region-Based Adaptive Perceptual Quantization Technique for MPEG Coder," *IEICE Trans. on Inf. and Sys.*, pp. 737-742, vol. E79, no. 6, Jun. 1996.

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